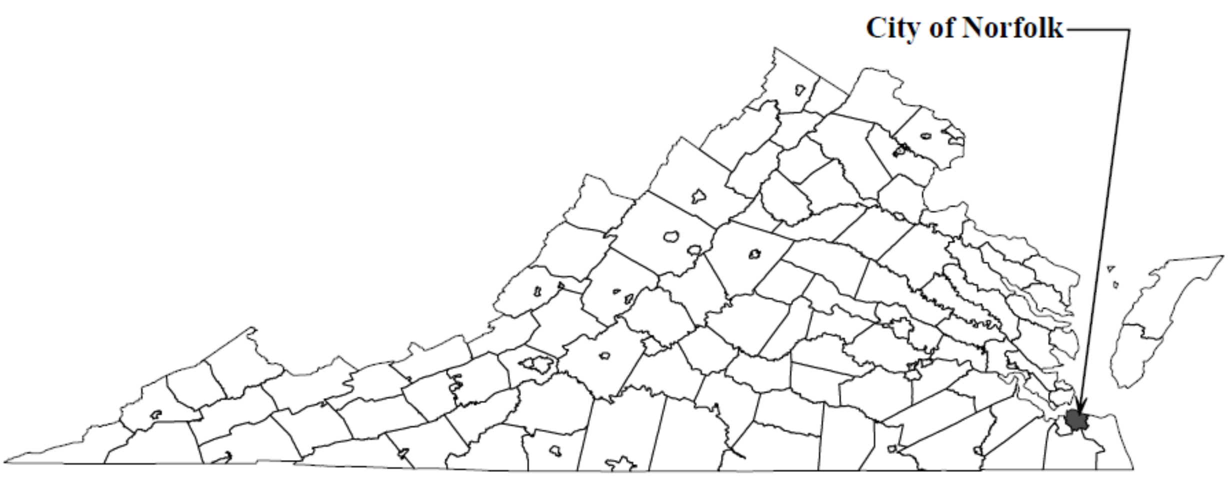
FLOOD INSURANCE STUDY

CITY OF NORFOLK, VIRGINIA
(INDEPENDENT CITY)



REVISED: **PRELIMINARY DATE AUGUST 14, 2014**

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
510104V000C

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

ATTENTION: On Flood Insurance Rate Map (FIRM) panel 0056G, the Elizabeth River Floodwall has not been demonstrated by the community or levee owner(s) to meet the requirements of Section 65.10 of the NFIP regulations in 44 CFR as it relates to the levee's capacity to provide 1% annual chance flood protection. The subject area is identified on the FIRM panel (with notes and bounding lines) and in the FIS report as potential areas of flood hazard data changes based on further review.

FEMA has updated levee analysis and mapping procedures for non-accredited levees. Until such time as FEMA is able to initiate a new flood risk project to apply the new procedures, the flood hazard information on the aforementioned FIRM panel that is affected by the Elizabeth River Floodwall is being added as a snapshot of the prior effective information presented on the FIRM and FIS report currently being revised. As indicated above, it is expected that affected flood hazard data within the subject area could be significantly revised. This may result in floodplain boundary changes, 1% annual chance flood elevation changes, and/or changes to flood hazard zone designations.

The effective FIRM panel (and the FIS report) will again be revised to update the flood hazard information associated with the Elizabeth River Floodwall when FEMA is able to initiate and complete a new flood risk project to apply the new levee analysis and mapping proceures.

Part or all of this FIS may be revised and republished at any time. In addition, part of this FIS may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the FIS. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current FIS components.

Initial FIS Effective Date:	February 1979 August 1, 1979 (Flood Insurance Rate Map (FIRM))
Revised FIS Dates:	September 2, 1982 March 2, 1983 (FIRM) – to include the effects of wave action April 17, 1984 – to change Base Flood Elevations (BFEs) July 16, 1996 – to update corporate limits, to change BFEs, and to change Special Flood Hazard Areas (SFHAs) September 2, 2009 – to add BFEs, to add floodways, to add SFHAs, to change zone designations, to change SFHAs, to update map format, and to reflect updated topographic information

TABLE OF CONTENTS

TABLE OF CONTENTS - continued

Page

FIGURES

TABLES

EXHIBITS

FLOOD INSURANCE STUDY
CITY OF NORFOLK, VIRGINIA (INDEPENDENT CITY)

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) revises and updates a previous FIS/Flood Insurance Rate Map (FIRM) for the geographic area of the City of Norfolk, Virginia. This information will be used by the City of Norfolk to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP). The information will also be used by local and regional planners to further promote sound land use and floodplain development.

This FIS aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This FIS has developed flood risk data for various areas of the county that will be used to establish actuarial flood insurance rates. This information will also be used by the City of Norfolk to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP), and will also be used by local and regional planners to further promote sound land use and floodplain development. Minimum floodplain management requirements for participation in Title 44 of the Code of Federal Regulations (CFR), Section 60.3.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the state (or other jurisdictional agency) will be able to explain them.

Please also note that FEMA has identified a levee in this jurisdiction that has not been demonstrated by the community or levee owner to meet the requirements of Section 65.10 of the NFIP regulations in 44 CFR as it relates to the levee’s capacity to provide 1% annual chance flood protection. As such, there are temporary actions being taken until such time as FEMA is able to initiate a new flood risk project to apply the new levee analysis and mapping procedures. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information.

1.2 Authority and Acknowledgments

The sources of authority for this FIS are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

For the original February 1979 FIS and August 1, 1979 FIRM, the hydrologic and hydraulic analyses were prepared by the Norfolk District of the U.S. Army Corps of Engineers (USACE) for the Federal Insurance Administration (FIA), under

Interagency Agreement No. IAA-H-10-77, Project Order No. 9, Amendment No. 2. That work was completed in February 1978.

FIS revisions made on September 2, 1982 (FIRM-March 2, 1983) and April 17, 1984 (FIRM-same date) included the effects of wave action along the Chesapeake Bay. The work was completed by Dewberry and Davis for the Federal Emergency Management Agency (FEMA).

The July 16, 1996 FIS revision included revised hydraulic analyses performed for Special Flood Hazard Areas (SFHAs) of Little Creek, along the Chesapeake Bay as a result of an annexation and FIS revision for the City of Virginia Beach (FEMA, 1996). The revised hydraulic analyses were prepared by USACE in March 1993.

The September 2, 2009 FIS revision, was prepared by USACE for FEMA, under Interagency Agreement No. HSFE03-04-X-0011, Project Order No. P394342Y and completed in April 2006. The September 2, 2009 FIS revised the 1996 study with an updated community description, historical flood information, FEMA contact information, and bibliography and references. The hydrologic and hydraulic analyses were not revised or updated for this FIS; however, effective flood elevations were converted and referenced to the North American Vertical Datum of 1988 (NAVD 88) and shown on the FIRM to the nearest tenth of a foot. The September 2, 2009 FIS also included information regarding survey bench marks, vertical datums, and datum conversion factors. The previous FIRM was converted to a digital format, utilizing updated aerial photography as the base map. Floodplain boundaries were also revised to reflect updated topographic data (Analytical Surveys, Inc., 1999). The previous FIRM panels were shown at a scale of 1:4,800; the revised FIRM panels were changed to a scale of 1:6,000.

For this FIS revision, the coastal analysis and mapping for the City of Norfolk was prepared for FEMA by Risk Assessment Mapping and Planning Partners (RAMPP) under Contract No. HSFEHQ-09-D-0369, Task Order HSFE03-09-J-0007 and finalized in December 2013.

For this FIS revision, base map information shown on the FIRM was provided by the Commonwealth of Virginia through the Virginia Base Mapping Program (VBMP). The orthophotos were flown in 2009 at scales of 1”:100’ and 1”:200’.

The projection used in the preparation of the FIRM is Universal Transverse Mercator (UTM) zone 18. The horizontal datum is the North American Datum of 1983 (NAD 83), Geodetic Reference System 1980 (GRS 80 spheroid).

1.3 Coordination

The purpose of an initial Consultation Coordination Officer's (CCO) meeting is to discuss the scope of the FIS. A final CCO meeting is held to review the results of the study. Contacts with various state and federal agencies are made during the study in order to minimize possible hydrologic and hydraulic conflicts. A search for basic data is made at all levels of government.

For the original February 1979 FIS, an initial CCO meeting was held on September 23, 1976 with representatives of the FIA, the City of Norfolk, and USACE. A final CCO meeting was held on August 31, 1978.

For the September 2, 1982 and April 17, 1984 revisions, a final CCO meeting was held on March 25, 1982 with representatives of FEMA, the City of Norfolk, and Dewberry and Davis.

For the July 16, 1996 revision, the city was notified by letter on May 13, 1994, that a revision to its FIS was being prepared.

For the September 2, 2009 revision, an initial CCO meeting was held on January 13, 2005 with representatives of FEMA, the City of Norfolk, the Virginia Department of Conservation and Recreation (DCR), and USACE (the study contractor). A final CCO meeting was held on June 11, 2008.

For this FIS revision, an initial CCO meeting was held on February 29, 2012 with representatives of the City of Norfolk, FEMA Region III, RAMPP, USACE, and the Virginia DCR.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the incorporated area of the City of Norfolk, Virginia.

For this FIS revision, updated coastal storm surge and wave height analyses were performed for the Chesapeake Bay and its adjoining estuaries and Elizabeth River, Hampton Roads, Lynnhaven River, and Mason Creek. All areas within the city which are affected by tidal flooding were included in the revision. Limits of Detailed Study are indicated on the FIRM (Exhibit 1). The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction. The scope and methods of the study were proposed to, and agreed upon by, FEMA and the City of Norfolk.

2.2 Community Description

The City of Norfolk is located on the south shore of the Chesapeake Bay approximately 20 miles west of the Atlantic Ocean in southeastern Virginia. The area, generally referred to as Hampton Roads, is formed by the confluence of the Chesapeake Bay and several tidal rivers. Norfolk is bordered by the City of Portsmouth on the west, the City of Chesapeake on the south, and the City of Virginia Beach on the east. Other neighboring cities include Suffolk to the southwest, and Hampton and Newport News to the northwest, across the harbor. Naval Station Norfolk, the world's largest naval base, borders the northwest portion of the city. Norfolk comprises a total area of 64 square miles, which includes approximately 10 square miles of water area. The population of Norfolk was 266,979 in 1980, 261,250 in 1990, 234,403 in 2000, 242,803 in 2010, and an estimated 245,782 in 2012 (U.S. Census Bureau, 2013).

The Town of Norfolk was established on August 16, 1682 with the purchase of 50 acres of land on the eastern branch of the Elizabeth River. On September 15, 1736, King George II issued a charter making it a borough. In 1845, Norfolk officially became incorporated as a city and has grown to become one of the world's largest harbors (City of Norfolk, 2013).

The city is located in the Atlantic Coastal Plain Province, an area typified by its low relief. Norfolk has an average land elevation of 13 feet above sea level. The city is bound on three sides by tidal waters, with numerous tributaries reaching inland areas, resulting in approximately 140 miles of shoreline. Soils consist primarily of unconsolidated sand and clay strata.

The area enjoys a temperate climate with moderate seasonal changes. The climate of Norfolk is characterized by moderately warm summers with temperatures averaging approximately 79 degrees Fahrenheit (^{o}F) during July, the warmest month. The winters are cool with temperatures averaging approximately 41^{o}F in January, the coolest month. Annual precipitation over the area averages approximately 45 inches. There is some variation in the monthly averages; however, this rainfall is distributed fairly uniformly throughout the year. Snowfall averages 8 inches each year, generally occurring in light falls which normally melt within 24 hours (Commerce, 2005).

The economy of Norfolk is diverse in many areas. The Federal government, higher education, manufacturing, port activity, residential construction, downtown business and residential development, and the medical and health professions provide economic assets to the city. With Norfolk's proximity to major transportation routes such as Interstates 64 and 95, its world class port, the Norfolk International Airport, and access to the railway system, economic development within the city is expected to continue and pressures leading to intensified floodplain use will undoubtedly accompany such development.

2.3 Principal Flood Problems

Past history of flooding in the City of Norfolk demonstrates that flooding can occur during any season of the year. Most serious tidal flooding problems are attributed to hurricanes, which occur during the late summer and early autumn. In addition to heavy precipitation, hurricanes produce high tides and strong waves, which can result in severe damage to coastal areas. Although extratropical cyclones, referred to as nor'easters, can develop at almost any time of the year, they are more likely to occur during the winter and spring. They originate with little or no warning along the middle and northern Atlantic coast. The accompanied winds are not of hurricane force but are persistent, causing above-normal tides for long periods of time. Thunderstorms are a common occurrence during the summer months.

Flood problems in the City of Norfolk result from abnormally high storm tides. Minor flooding, up to elevations 4 to 5 feet, is associated with periods of moderately high sustained winds from the northeast, north, and northwest, which may be experienced several times within any one year. The main sources of concern are the large and infrequent floods, which are associated with major storm events that push the waters of the Atlantic Ocean westward through the Chesapeake Bay. The type of storm which affects the area most severely is the hurricane with its high winds and heavy rainfall, which produces large waves and tidal flooding. The term hurricane is applied to an intense cyclonic storm originating in tropical or subtropical latitudes in the Atlantic Ocean just north of the equator. While hurricanes may affect the area from May through December, most hurricane activity is likely from June through November, with maximum activity occurring in early to mid September.

The amount and extent of damage caused by any tidal flood will depend upon the topography of the area flooded, rate of rise of floodwaters, the depth and duration of flooding, the exposure to wave action, and the extent to which structures have been placed in the floodplain. The depth of flooding during these storms depends upon the velocity, direction, and duration of the wind; the size and depth of the body of water over which the wind is acting; and the astronomical tide. The duration of flooding depends upon the duration of the tide-producing forces. Floods caused by hurricanes are usually of much shorter duration than those caused by nor'easters. Flooding from hurricanes rarely lasts more than one tidal cycle, while flooding from nor'easters may last several days, during which the most severe flooding takes place at the time of the peak astronomical tide.

The timing or coincidence of the maximum storm surge with the normal high tide is an important factor in the consideration of flooding from tidal sources. Tidal waters in the study area normally fluctuate twice daily with a mean tide range of approximately 2.6 feet (Commerce, NOAA, NOS, Center for Operational Oceanographic Products and Services, 2006). The range is somewhat less in most of the connecting bays and inlets.

All development in the floodplain is subject to water damage. Some areas, depending upon exposure, are subject to high velocity wave action which may cause structural damage and severe erosion along beaches. Waves are generated by the action of wind on the surface of the water. Wave heights at any location are dependent upon the velocity, direction, and duration of the wind, and the length, width, and depth of water over which the wind is acting. The Ocean View-Willoughby area, adjacent to the Chesapeake Bay, is the most vulnerable area of the city for wave damage, because of the vast exposure afforded by the Chesapeake Bay.

The City of Norfolk has experienced major storms since its early settlement. Historical accounts of severe storms in the Hampton Roads area date back several hundred years. The following paragraphs discuss some of the larger known storms which have occurred in recent history. This information is based on newspaper accounts, historical records, field investigations, and routine data collection programs normally conducted by the USACE.

Hurricanes and major storms have produced significant flooding conditions on the southeastern coast of Virginia in 1933, 1936, 1956, 1962, 2003 and 2012.

<u>August 1933</u>

This hurricane was one of the most severe storms ever to occur in the middle Atlantic region. The eye passed directly over Hampton Roads and caused the most extensive flooding experienced in Norfolk in the past 200 years. The maximum storm surge produced was the greatest of record and occurred about 3 hours before, but persisted through the peak of the astronomical tide. The water level reached an approximate elevation of 7 feet, in Norfolk. Extensive damage to harbor and shipping, waterfront property, and low-lying buildings occurred during this flood. In addition to damage from tidal flooding, much damage was caused to roofs, communication lines, and other structures by the high wind. Damage of this nature is characteristic of that caused by hurricanes (The Norfolk Ledger Dispatch, 1933; Pilot and Norfolk Landmark, 1933; USACE: Norfolk District, 1970).

Excerpts from *The Norfolk Ledger Dispatch*, August 23, 1933:

"The entire spit from the Nansemond Hotel to the point was under water and at some sections high waves rushed across from Chesapeake Bay to Little Bay."

Excerpts from *A Pictorial Record of Tidewater's Worst Storm,* August 22 and 23, 1933 (Pilot and Norfolk Landmark, 1933):

"Untold property damage and an almost complete paralysis of transportation, communication and business was the toll of the tropical hurricane that swept Tidewater, Virginia, Tuesday night and Wednesday morning, August 22nd and 23rd, 1933."

"The storm, the worst in this section raged for hours, leveling or damaging hundreds of homes, uprooting thousands of trees driving before it, tide water of unprecedented depths."

"Homes and retail stores in the cities were turned into veritable islands – beach resorts were lashed and whipped in many cases to complete destruction."

September 18, 1936

The eye of the hurricane passed approximately 20 miles east of Cape Henry. High tides and gale force winds caused much damage throughout the lower Chesapeake Bay area as the storm moved off to the northeast. In Norfolk, the elevation of flooding was approximately 0.5 foot less than the storm of August 1933 (USACE: Norfolk District, 1970).

April 11, 1956

The nor'easter produced a steady wind in the lower Chesapeake Bay area for about 30 hours. The tides ran about 4 feet above normal for about 12 hours and crested on April 11th. Large areas of low-lying sections of the city were inundated during the storm. In Norfolk, the elevation of flooding was approximately 1.5 feet less than the storm of August 1933 (USACE: Norfolk District, 1970).

March 6-8, 1962

This nor'easter caused disastrous flooding and high waves all along the Atlantic Seaboard from New York to Florida. This storm was unusual even for a nor'easter since it was caused by a low pressure cell which moved from south to north past Hampton Roads and then reversed its course, moving again to the south bringing with it huge volumes of water and high waves which battered the mid-Atlantic coastline for several days. The maximum flood height was approximately 0.5 foot less than the storm of August 1933 in Norfolk. The hardest hit sections of the city were the residential and resort communities of East Ocean View and Willoughby Spit on the Chesapeake Bay and the central business district in downtown Norfolk. In addition to the high tides, storm waves of 7 to 10 feet in height were reported along the south shore of the Chesapeake Bay. These waves battered the shoreline for several days (The Norfolk Ledger Dispatch and Portsmouth Star, 1962).

Excerpts from "The Norfolk Ledger Dispatch and Portsmouth Star," March 7, 1962:

"At mid-morning there were 16 inches of water inside the hub at the corner of Granby Street and City Hall Avenue."

"Willoughby Spit which has been hit time and again by storms raging in from the sea, today was lashed by winds and waters that longtime residents say are the worst they've ever experienced."

"Reports from households all along West Ocean View Avenue from Granby Street to the Hampton Roads Bridge Tunnel indicate waist-high waters cover almost the entire area from Little Bay to the Chesapeake Bay side of the spit."

September 16, 1999

Hurricane Floyd, at one time a large Category 4 storm, had weakened to a minimal hurricane as it reached Virginia. However, rain associated with Floyd began well in advance of the storm and intensified as the storm neared and crossed Virginia Beach on the 16th. Rainfall amounts averaged 10 to 20 inches in a 50 to 75 mile path over southeast Virginia. More than 300 roads were closed in the peak of the storm from flooding and downed trees. Flooding caused $30 million to $40 million. The hardest hit counties were Southampton, Sussex, Isle of Wight and Surry. The city of Franklin experienced a record flood with 206 businesses impacted and numerous homes. Two people died in flooding in the state. The highest sustained wind recorded over land was only 46 mph at Langley Air Force Base with a gust to 63 mph. The James River Bridge recorded a wind gust of 100 mph. The saturated ground from Floyd combined with the wind and led to trees uprooting and widespread power outages. Two people were killed by falling trees. Total storm damage in Virginia reached $255 million with 64 jurisdictions affected. (Virginia Department of Emergency Management, 2012).

September 18, 2003

The most recent tidal stage of major proportions occurred during Hurricane Isabel, making landfall on September 18, 2003 along the Outer Banks of North Carolina and tracking northward through Virginia and up to Pennsylvania. At landfall, maximum sustained winds were estimated at 104 mph. Isabel weakened to a tropical storm by the time it moved into Virginia and lost tropical characteristics as it moved into Pennsylvania. The storm caused high winds, storm surge flooding, and extensive property damage throughout the Chesapeake Bay region. Within Virginia, ninety-nine communities were directly affected by Isabel. There were thirty-three deaths, over a billion dollars in property damage, and over a million electrical customers without power for many days (Commonwealth of Virginia, 2003). Historical maximum water level records were exceeded at several locations within the Chesapeake Bay area. In general, maximum water levels in the lower Chesapeake Bay resembled those of the August 1933 hurricane, with storm surge occurring around the time of the predicted high tide. Some communities along the Chesapeake Bay and its tributaries also experienced severe damage from wave action (NOAA, April 2004).

October 29, 2012

“Superstorm Sandy” the deadliest and most destructive hurricane of the 2012 hurricane season affected the east coast. It affected 24 states, including the entire eastern seaboard from Florida to Maine with particularly severe damage in New Jersey and New York. On October 26, 2012 Virginia Governor Bob McDonnell declared a state of emergency. The US Navy sent ships and forces to sea from the Norfolk Naval Base for their protection and the National Guard was authorized to activate 630 personnel ahead of the storm. There was significant flooding in

Norfolk, where authorities closed the Midtown Tunnel and some low-lying areas were evacuated.

2.4 Flood Protection Measures

Within this jurisdiction there are one or more levees that have not been demonstrated by the community or levee owner(s) to meet the requirements of Section 65.10 of the NFIP Regulations in 44 CFR as it relates to the levee's capacity to provide 1% annual chance flood protection. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information.

There are no existing flood control structures that would provide protection during major floods in the city. There are a number of measures that have afforded some protection against flooding, including bulkheads and seawalls and non-structural measures for floodplain management such as zoning codes.

According to the Southside Hampton Roads Hazard Mitigation Plan (2011), the City's Capital Improvement Plan has been the primary vehicle for integrating mitigation goals into administrative actions. As of September 2011, these mitigation activities have been completed: the execution of a wind retrofit of the Fleet Maintenance Facility and the Solid Waste Facility; numerous Hazard Mitigation Grant Program (HMGP) projects (buyouts and elevations) post Floyd (1999) and Isabel (2003); automated flood data collection system; flood mitigation planning with Fugro Atlantic; and maintained Class 9 Community Rating System (CRS) rating.

A critical part of a comprehensive emergency management program is the successful implementation of hazard mitigation actions. The City of Norfolk has or is involved in the following: Emergency Operations Plan, Radiological Emergency Plan, Superfund Amendments and Reauthorization Act (SARA) Title III Emergency Response Plan, Comprehensive Land Use Plan, Capital Improvements Plan, Historic Preservation Plan, Zoning Ordinances, Subdivision Ordinances, Building Codes, Permitting and Inspections and Stormwater Management Plan.

The CRS is an incentive program that encourages communities to undertake defined flood mitigation activities that go beyond the minimum requirements of the NFIP, adding extra local measures to provide protection from flooding. Community participation in the CRS is voluntary. The City of Norfolk participates in the CRS. It has achieved Class 9 ratings.

On January 24, 2006, Norfolk became the first major East Coast city with a tsunami emergency response plan to alert residents and visitors of tsunami threats, and evacuate areas if necessary. The National Oceanic and Atmospheric

Administration (NOAA) officially recognized the City of Norfolk as a “Tsunami Ready” community.

3.0 ENGINEERING METHODS

For the flooding sources studied by detailed methods in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this FIS. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1-percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this FIS. Maps and flood elevations will be amended periodically to reflect future changes.

Note: Within this jurisdiction there are one or more levees that have not been demonstrated by the community or levee owner(s) to meet the requirements of Section 65.10 of the NFIP Regulations in 44 CFR as it relates to the levee’s capacity to provide 1% annual chance flood protection. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information.

3.1 Coastal Analyses

For this FIS, coastal analyses, considering storm characteristics and the shoreline and bathymetric characteristics of the flooding sources studied, were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along the shoreline. Users of the FIRM should be aware that coastal flood elevations are provided in Table 1, “Summary of Stillwater Elevations” table in this report. If the elevation on the FIRM is higher than the elevation shown in this table, a wave height, wave runup, and/or wave setup component likely exists, in which case, the higher elevation should be used for construction and/or floodplain management purposes. The coastal analyses involved transect layout, field reconnaissance, erosion analysis, and overland wave modeling including wave setup, wave height analysis and wave runup.

The end-to-end storm surge modeling system includes the Advanced Circulation Model for Oceanic, Coastal and Estuarine Waters (ADCIRC) for simulation of 2-dimensional hydrodynamics (Luettich et. al, 2008). ADCIRC was dynamically coupled to the unstructured numerical wave model Simulating WAves Nearshore (unSWAN) to calculate the contribution of waves to total storm surge (USACE, 2012). The resulting model system is typically referred to as SWAN+ADCIRC (USACE, 2012). A seamless modeling grid was developed to support the storm surge modeling efforts. The modeling system validation consisted of a comprehensive tidal calibration followed by a validation using carefully reconstructed wind and pressure fields from three major flood events for the FEMA Region III domain: Hurricane Isabel, Hurricane Ernesto, and Extratropical Storm Ida. Model skill was accessed by quantitative comparison of model output to wind, wave, water level and high water mark observations.

The storm surge study was conducted for FEMA by the US Army Corps of Engineers (USACE) and its project partners under Project HSFE03-06-X-0023, “NFIP Coastal Storm Surge Model for Region III” and Project HSFE03-09-X-1108, “Phase III Coastal Storm Surge Model for FEMA Region III”. The work was performed by the Coastal Processes Branch (HF-C) of the Flood and Storm Protection Division (HF), U.S. Army Engineer Research and Development Center – Coastal & Hydraulics Laboratory (ERDC-CHL).

The tidal surge from the Chesapeake Bay/Hampton Roads affects the entire shoreline within the City of Norfolk. Open coastline areas, from the Elizabeth River to Little Creek, along the Hampton Roads/Chesapeake Bay shoreline, are more prone to damaging wave action during high wind events due to the significant fetch over which winds can operate. Behind the coastline, those areas still prone to coastal flooding gently rise in elevation and narrow considerably as they converge with upland residential and industrial areas. In these areas, the fetch over which winds can operate for wave generation are significantly less.

The storm-surge elevations for the 10-, 2-, 1-, and 0.2-percent annual chance floods were determined for Chesapeake Bay/Hampton Roads and are shown in Table 1, “Summary of Stillwater Elevations.” The analyses reported herein reflect the stillwater elevations due to tidal and wind setup effects.

TABLE 1 - SUMMARY OF STILLWATER ELEVATIONS

FLOODING SOURCE AND LOCATION	ELEVATION (feet NAVD*)			
	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
HAMPTON ROADS/ CHESAPEAKE BAY AND TRIBUTARIES				
Elizabeth River at Washington Point	5.7	7.2	7.9	9.8
Elizabeth River at Lamberts Point	5.6	7.1	8.8	9.6
Lynnhaven River at Julians Neck	5.4	6.8	7.5	9.2

*North American Vertical Datum of 1988

TABLE 1 - SUMMARY OF STILLWATER ELEVATIONS – continued

FLOODING SOURCE AND LOCATION	ELEVATION (feet NAVD*) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
HAMPTON ROADS/ CHESAPEAKE BAY AND TRIBUTARIES				
Hampton Roads at Sewells Point	5.1	6.8	7.2	8.6
Chesapeake Bay at western end of Willoughby Spit	5.1	6.6	7.2	8.7
Chesapeake Bay at Little Creek	5.0	6.4	7.0	8.4

*North American Vertical Datum of 1988

3.2 Wave Height Analysis

The wave height analysis was carried out to provide estimates of the elevations of floods of the selected recurrence intervals along the shoreline of the Atlantic Ocean and inland bays.

The destructiveness of high stillwater elevations due to coastal flooding may be increased by wind-induced waves, which contribute to increased water levels, and whose size and velocity may damage structures directly. The height of a wave is dependent upon wind speed and its duration, depth of water, and length of fetch. The wave crest elevation is the sum of the stillwater elevation and the portion of the wave height above the stillwater elevation.

The methodology for analyzing the effects of wave heights associated with coastal storm surge flooding is described in a report prepared by the National Academy of Sciences (NAS, 1977). This method is based on three major concepts. First, depth-limited waves in shallow water reach maximum breaking height that is equal to 0.78 times the stillwater depth. The wave crest is 70 percent of the total wave height above the stillwater level. The second major concept is that wave height may be diminished by dissipation of energy due to the presence of obstructions, such as sand dunes, dikes and seawalls, buildings and vegetation. The amount of energy dissipation is a function of the physical characteristics of the obstruction and is determined by procedures prescribed in NAS report. The third major concept is that wave height can be regenerated in open fetch areas due to the transfer of wind energy to the water. This added energy is related to fetch length and depth.

Transects represent the locations where the overland wave height analysis was modeled and were placed with consideration given to topography, land use, shoreline features and orientation, and the available fetch distance. Each transect was placed to capture the dominant wave direction, typically perpendicular to the shoreline, and extended inland to a point where coastal flooding ceased. Along each transect, wave heights were computed considering the combined effects of changes in ground elevation, obstructions, and wind contributions. Transects were placed along the shoreline along all sources of primary flooding in the county, as illustrated on the FIRM and in Figure 1, “Transect Location Map”. Transects also represent locations visited during field reconnaissance to assist in parameterizing obstructions and observing shore protection features.

Wave heights were computed across transects that were located along coastal areas in the of City of Norfolk, as illustrated on the FIRM. The transects were located with consideration given to existing transect locations and to the physical and cultural characteristics of the land so that they would closely represent conditions in the locality.

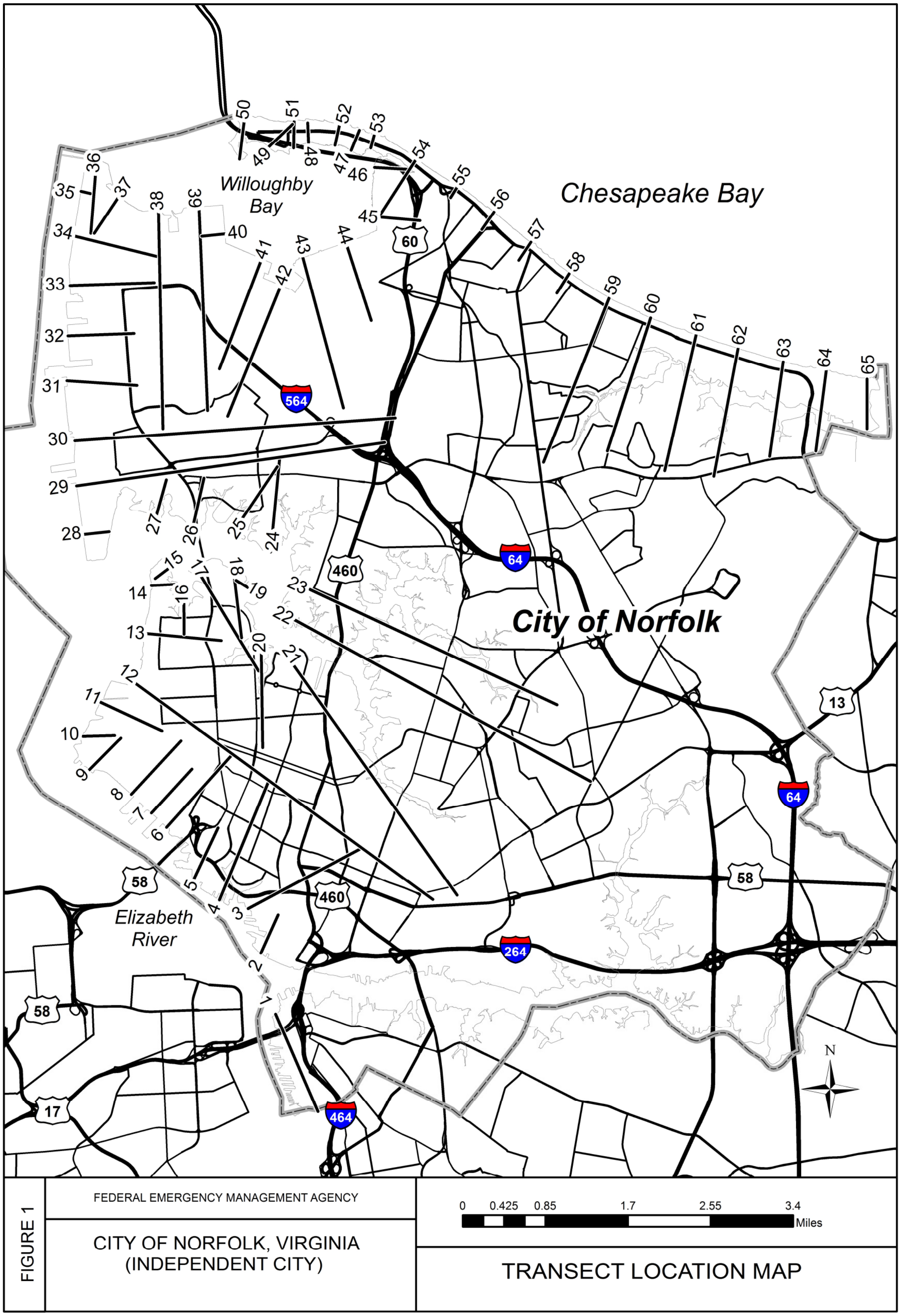


FIGURE 1 – TRANSECT LOCATION MAP

Each transect was taken perpendicular to the shoreline and extended inland to a point where coastal flooding ceased. Along each transect, wave heights and elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. The stillwater elevations for a 1-percent annual chance event were used as the starting elevations for these computations. Wave heights were calculated to the nearest 0.1 foot, and wave elevations were determined at whole-foot increments along the transects. The location of the 3-foot breaking wave for determining the terminus of the Zone VE (area with velocity wave action) was computed at each transect. Along the open coast, the Zone VE designation applies to all areas seaward of the landward toe of the primary frontal dune system. The primary frontal dune is defined as the point where the ground profile changes from relatively steep to relatively mild.

Dune erosion was taken into account along selected areas of the Hampton Roads/Chesapeake Bay coastline. A review of the geology and shoreline type in the City of Norfolk was made to determine the applicability of standard erosion methods, and FEMA's standard erosion methodology for coastal areas having primary frontal dunes, referred to as the "540 rule," was used (FEMA, 2007a). This methodology first evaluates the dune's cross-sectional profile to determine whether the dune has a reservoir of material that is greater or less than 540 square feet. If the reservoir is greater than 540 square feet, the "retreat" erosion method is employed and approximately 540 square feet of the dune is eroded using a standardized eroded profile, as specified in FEMA guidelines. If the reservoir is less than 540 square feet, the "remove" erosion method is employed where the dune is removed for subsequent analysis, again using a standard eroded profile. The storm surge study provided the return period stillwater elevations required for erosion analyses. Each cross-shore transect was analyzed for erosion, when applicable.

Wave height calculations used in this study follow the methodologies described in the FEMA guidance for coastal mapping (FEMA, 2007a). Wave setup results in an increased water level at the shoreline due to the breaking of waves and transfer of momentum to the water column during hurricanes and severe storms. For the City of Norfolk study, wave setup was determined directly from the coupled wave and storm surge model, the total stillwater elevation (SWEL) with wave setup was then used for simulations of inland wave propagation conducted using FEMA's Wave Height Analysis for Flood Insurance Studies (WHAFIS) model Version 4.0 (FEMA, 2007b). WHAFIS is a one-dimensional model that was applied to each transect in the study area. The model uses the specified SWEL, the computed wave setup, and the starting wave conditions as input. Simulations of wave transformations were then conducted with WHAFIS taking into account the storm-induced erosion and overland features of each transect. Output from the model includes the combined SWEL and wave height along each cross-shore transect allowing for the establishment of base flood elevations (BFEs) and flood zones from the shoreline to points inland within the study area.

Wave runup is defined as the maximum vertical extent of wave uprush on a beach or structure. FEMA's 2007 Guidelines and Specifications require the 2- percent wave runup level be computed for the coastal feature being evaluated (cliff, coastal bluff, dune, or structure) (FEMA, 2007a). The 2- percent runup level is the highest 2- percent of wave runup affecting the shoreline during the 1-percent-annual-chance flood event. Each transect defined within the FEMA Region III study area was evaluated for the applicability of wave runup, and if necessary, the appropriate runup methodology was selected and applied to each transect. Runup elevations were then compared to WHAFIS results to determine the dominant process affecting BFEs and associated flood hazard levels. Based on wave runup rates, wave overtopping was computed following the FEMA 2007 Guidelines and Specifications.

Computed controlling wave height at the shoreline ranges from 1.2 feet to 6.1 feet. The corresponding wave elevation at the shoreline varies from 1.2 feet to 12.8 feet. Vertical reinforced coastlines serve to reduce wave heights. The dune along the coast serves to reduce wave height transmitted inland, but the large areas of low-lying marshes which are inundated by the tidal surge allow regeneration of the waves as they proceed inland. In general, the relatively shallow depth of water in the marshes along with the energy dissipating effects of vegetation allow only minor regeneration of the waves.

Areas of coastline subject to significant wave attack are referred to as coastal high hazard areas. The USACE has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard areas (USACE, 1975). The 3-foot wave has been determined the minimum size wave capable of causing major damage to conventional wood frame or brick veneer structures. The one exception to the 3-foot wave criteria is where a primary frontal dune exists. The limit of the coastal high hazard area then becomes the landward toe of the primary frontal dune or where a 3-foot or greater breaking wave exists, whichever is most landward. The coastal high hazard zone is depicted on the FIRM as Zone VE, where the delineated flood hazard includes wave heights equal to or greater than 3 feet. Zone AE is depicted on the FIRM where the delineated flood hazard includes wave heights less than 3 feet. A depiction of how the Zones VE and AE are mapped is shown in Figure 2 “Transect Schematic.”

Post-storm field visits and laboratory tests have confirmed that wave heights as small as 1.5 feet can cause significant damage to structures when designed without consideration to the coastal hazards. Additional flood hazards associated with coastal waves include floating debris, high velocity flow, erosion, and scour which can cause damage to Zone AE-type construction in these coastal areas. To help community officials and property owners recognize this increased potential for damage due to wave action in the AE zone, FEMA issued guidance in December 2008 on identifying and mapping the 1.5-foot wave height line, referred to as the Limit of Moderate Wave Action (LiMWA). While FEMA does not impose floodplain management requirements based on the LiMWA, the LiMWA is provided to help communicate the higher risk that exists in that area. Consequently, it is important to be aware of the area between this inland limit and the Zone VE boundary as it still poses a high risk, though not as high of a risk as Zone VE (see Figure 2).

Figure 2 is a profile for a typical transect illustrating the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave crest elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Actual wave conditions in the City of Norfolk may not include all the situations illustrated in Figure 2.

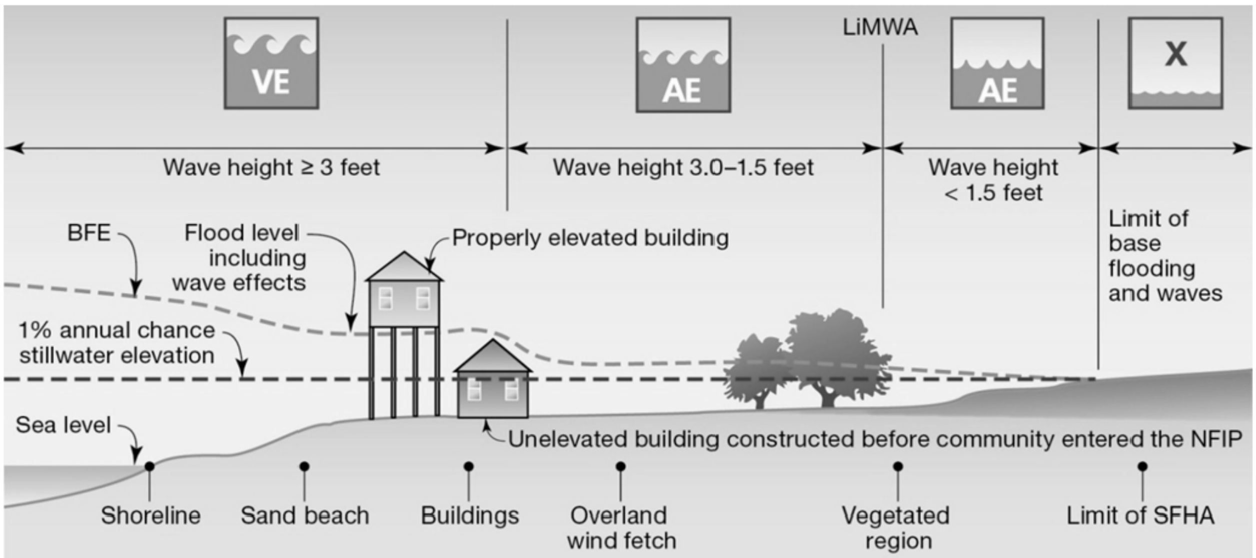


FIGURE 2 – TRANSECT SCHEMATIC

Between transects, elevations were interpolated using topographic maps, land-use and land cover data, and engineering judgment to determine the aerial extent of flooding. The results of the calculations are accurate until local topography, vegetation, or cultural development within the community undergo major changes. The Transect Data table, Table 2, provides 10-, 2-, 1-, and 0.2- percent annual chance stillwater elevations and the starting wave conditions for each transect.

TABLE 2 – TRANSECT DATA

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (**ft NAVD88**)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
ELIZABETH RIVER	1	N 36.836123 W -76.291664	2.2	2.9	5.7	7.2	7.9	9.8
ELIZABETH RIVER	2	N 36.845102 W -76.294327	2.4	3.0	5.7	7.2	7.9	9.8
ELIZABETH RIVER	3	N 36.851789 W -76.296672	2.4	2.9	5.7	7.2	7.8	9.8
ELIZABETH RIVER	4	N 36.853086 W -76.301960	2.4	2.9	5.7	7.2	7.8	9.7
ELIZABETH RIVER	5	N 36.855711 W -76.306951	2.6	3.1	5.7	7.2	7.8	9.7
ELIZABETH RIVER	6	N 36.863957 W -76.311673	2.6	3.0	5.6	7.1	7.8	9.7
ELIZABETH RIVER	7	N 36.866109 W -76.314454	2.6	2.9	5.6	7.1	7.8	9.7
ELIZABETH RIVER	8	N 36.868889 W -76.318094	2.5	2.8	5.6	7.1	7.8	9.6
ELIZABETH RIVER	9	N 36.872597 W -76.325916	2.7	3.0	5.6	7.1	7.8	9.6
ELIZABETH RIVER	10	N 36.877542 W -76.327020	3.2	3.5	5.6	7.1	7.7	9.5

[1]Stillwater elevations include the contribution from wave setup.

TABLE 2 – TRANSECT DATA – continued

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (**ft NAVD88**)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
ELIZABETH RIVER	11	N 36.882586 W -76.323787	3.6	3.6	5.6	7.1	7.7	9.5
ELIZABETH RIVER	12	N 36.885585 W -76.317514	3.7	3.7	5.6	7.1	7.7	9.6
ELIZABETH RIVER	13	N 36.892751 W -76.315445	3.6	3.6	5.5	7.0	7.6	9.5
ELIZABETH RIVER	14	N 36.899847 W -76.314100	3.0	3.1	5.5	6.9	7.6	9.4
ELIZABETH RIVER	15	N 36.902391 W -76.310843	1.9	2.5	5.5	6.9	7.5	9.3
ELIZABETH RIVER	16	N 36.899048 W -76.308111	2.0	2.8	5.5	6.9	7.6	9.4
ELIZABETH RIVER	17	N 36.902932 W -76.306164	2.0	2.6	5.5	6.8	7.5	9.3
ELIZABETH RIVER	18	N 36.901476 W -76.298753	1.9	2.5	5.4	6.8	7.5	9.4
ELIZABETH RIVER	19	N 36.898483 W -76.294336	1.8	2.5	5.5	6.8	7.5	9.5
ELIZABETH RIVER	20	N 36.890918 W -76.293809	1.8	2.5	5.5	6.9	7.6	9.6

[1]Stillwater elevations include the contribution from wave setup.

TABLE 2 – TRANSECT DATA – continued

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (**ft NAVD88**)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
ELIZABETH RIVER	21	N 36.889831 W -76.289538	1.8	2.5	5.5	6.9	7.6	9.6
ELIZABETH RIVER	22	N 36.898872 W -76.290280	1.8	2.5	5.5	6.9	7.5	9.5
ELIZABETH RIVER	23	N 36.900278 W -76.287701	1.9	2.5	5.5	6.8	7.6	9.4
ELIZABETH RIVER	24	N 36.904666 W -76.291921	1.9	2.5	5.4	6.8	7.5	9.4
ELIZABETH RIVER	25	N 36.907650 W -76.298923	1.9	2.5	5.4	6.8	7.5	9.3
ELIZABETH RIVER	26	N 36.907891 W -76.306523	2.0	2.6	5.4	6.8	7.5	9.3
ELIZABETH RIVER	27	N 36.910044 W -76.313167	2.1	2.6	5.4	6.8	7.5	9.2
ELIZABETH RIVER	28	N 36.907488 W -76.326675	4.0	4.0	5.4	6.9	7.6	9.2
ELIZABETH RIVER	29	N 36.914792 W -76.327796	4.2	4.0	5.4	6.9	7.5	9.2
ELIZABETH RIVER	30	N 36.921478 W -76.328166	4.9	4.1	5.4	6.9	7.5	9.2

[1]Stillwater elevations include the contribution from wave setup.

TABLE 2 – TRANSECT DATA – continued

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (**ft NAVD88**)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
HAMPTON ROADS	31	N 36.930331 W -76.329521	5.3	4.2	5.3	6.8	7.4	9.0
HAMPTON ROADS	32	N 36.937001 W -76.329236	5.4	4.3	5.3	6.8	7.4	8.9
HAMPTON ROADS	33	N 36.944522 W -76.328824	5.6	4.7	5.3	6.8	7.4	8.9
HAMPTON ROADS	34	N 36.951860 W -76.328050	6.0	4.8	5.2	6.7	7.3	8.8
HAMPTON ROADS	35	N 36.958481 W -76.326652	6.0	5.4	5.2	6.7	7.3	8.7
HAMPTON ROADS	36	N 36.963157 W -76.323709	5.6	5.8	5.1	6.6	7.2	8.6
WILLOUGHBY BAY	37	N 36.957669 W -76.319954	6.7	6.2	5.3	6.8	7.4	8.8
WILLOUGHBY BAY	38	N 36.955637 W -76.312260	6.5	6.2	5.3	6.8	7.4	8.8
WILLOUGHBY BAY	39	N 36.956102 W -76.304769	5.9	6.3	5.2	6.8	7.4	8.8
WILLOUGHBY BAY	40	N 36.951969 W -76.299894	4.3	3.6	5.3	6.8	7.4	8.9

[1]Stillwater elevations include the contribution from wave setup.

TABLE 2 – TRANSECT DATA – continued

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (**ft NAVD88**)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
WILLOUGHBY BAY	41	N 36.948296 W -76.293158	3.9	3.3	5.3	6.8	7.4	8.9
WILLOUGHBY BAY	42	N 36.944337 W -76.289641	2.7	3.4	5.3	6.8	7.4	9.0
WILLOUGHBY BAY	43	N 36.948479 W -76.285537	3.6	3.2	5.3	6.8	7.4	8.9
WILLOUGHBY BAY	44	N 36.950574 W -76.277482	2.8	2.9	5.3	6.8	7.3	8.9
WILLOUGHBY BAY	45	N 36.954344 W -76.271757	2.5	2.8	5.2	6.7	7.3	8.8
WILLOUGHBY BAY	46	N 36.961654 W -76.272070	2.4	2.3	5.2	6.7	7.3	8.7
WILLOUGHBY BAY	47	N 36.964233 W -76.276362	2.4	2.5	5.2	6.7	7.3	8.7
WILLOUGHBY BAY	48	N 36.965411 W -76.284270	2.5	2.7	5.2	6.7	7.3	8.7
WILLOUGHBY BAY	49	N 36.964849 W -76.291659	2.5	2.5	5.2	6.7	7.3	8.7
CHESAPEAKE BAY	50	N 36.969567 W -76.296086	8.7	7.2	5.1	6.6	7.2	8.5

[1]Stillwater elevations include the contribution from wave setup.

TABLE 2 – TRANSECT DATA – continued

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (**ft NAVD88**)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESAPEAKE BAY	51	N 36.966316 W -76.287061	9.7	7.3	5.1	6.7	7.3	8.6
CHESAPEAKE BAY	52	N 36.968142 W -76.278469	10.5	7.3	5.2	6.6	7.2	8.5
CHESAPEAKE BAY	53	N 36.966430 W -76.272075	11.0	7.3	5.1	6.6	7.2	8.5
CHESAPEAKE BAY	54	N 36.962940 W -76.264211	11.4	7.3	5.1	6.6	7.2	8.6
CHESAPEAKE BAY	55	N 36.958808 W -76.256598	11.8	7.2	5.0	6.5	7.1	8.5
CHESAPEAKE BAY	56	N 36.954962 W -76.249956	12.1	7.3	5.0	6.5	7.1	8.5
CHESAPEAKE BAY	57	N 36.950472 W -76.243043	12.2	7.3	5.0	6.5	7.1	8.6
CHESAPEAKE BAY	58	N 36.945963 W -76.235927	12.0	7.3	5.1	6.5	7.1	8.6
CHESAPEAKE BAY	59	N 36.942135 W -76.228617	12.2	7.3	5.1	6.5	7.1	8.6
CHESAPEAKE BAY	60	N 36.939190 W -76.221074	12.0	7.2	5.1	6.5	7.1	8.6

[1]Stillwater elevations include the contribution from wave setup.

TABLE 2 – TRANSECT DATA – continued

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (**ft NAVD88**)			
		Coordinates	Significant Wave Height H_s (**ft**)	Peak Wave Period T_p (**sec**)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESAPEAKE BAY	61	N 36.936769 W -76.212530	12.1	7.2	5.1	6.5	7.1	8.6
CHESAPEAKE BAY	62	N 36.934452 W -76.204802	12.2	7.2	5.1	6.5	7.1	8.6
CHESAPEAKE BAY	63	N 36.932386 W -76.196439	11.9	7.2	5.1	6.5	7.1	8.6
CHESAPEAKE BAY	64	N 36.931026 W -76.188394	11.8	7.2	5.0	6.5	7.0	8.5
CHESAPEAKE BAY	65	N 36.929654 W -76.180869	11.7	7.1	5.0	6.4	7.0	8.4

[1]Stillwater elevations include the contribution from wave setup.

Qualifying bench marks within a given jurisdiction that are cataloged by the National Geodetic Survey (NGS) and entered into the National Spatial Reference System (NSRS) as First or Second Order Vertical and have a vertical stability classification of A, B, or C are shown and labeled on the FIRM with their 6-character NSRS Permanent Identifier.

Bench marks cataloged by the NGS and entered into the NSRS vary widely in vertical stability classification. NSRS vertical stability classifications are as follows:

- Stability A: Monuments of the most reliable nature, expected to hold position/elevation well (e.g., mounted in bedrock)

- Stability B: Monuments which generally hold their position/elevation well (e.g., concrete bridge abutment)

- Stability C: Monuments which may be affected by surface ground movements (e.g., concrete monument below frost line)

- Stability D: Mark of questionable or unknown vertical stability (e.g., concrete monument above frost line, or steel witness post)

In addition to NSRS bench marks, the FIRM may also show vertical control monuments established by a local jurisdiction; these monuments will be shown on the FIRM with the appropriate designations. Local monuments will only be placed on the FIRM if the community has requested that they be included, and if the monuments meet the aforementioned NSRS inclusion criteria.

To obtain current elevation, description, and/or location information for bench marks shown on the FIRM for this jurisdiction, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit its web site at www.ngs.noaa.gov.

It is important to note that temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the Technical Support Data Notebook associated with this FIS and FIRM. Interested individuals may contact FEMA to access this data.

3.3 Vertical Datum

All FISs and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum in use for newly created or revised FISs and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD29). With the finalization of the North

American Vertical Datum of 1988 (NAVD88), many FIS reports and FIRMs are being prepared using NAVD88 as the referenced vertical datum.

All flood elevations shown in this FIS report and on the FIRM are referenced to NAVD88. Structure and ground elevations in the community must, therefore, be referenced to NAVD88. It is important to note that adjacent communities may be referenced to NGVD29. This may result in differences in base flood elevations across the corporate limits between the communities.

As noted above, the elevations shown in this FIS report and on the FIRM for the City of Norfolk are referenced to NAVD88. Ground, structure, and flood elevations may be compared and/or referenced to NGVD29 by applying a standard conversion factor. The conversion factor to NGVD29 is +0.89. The BFEs shown on the FIRM represent whole-foot rounded values. For example, a BFE of 102.4 will appear as 102 on the FIRM and 102.6 will appear as 103. Therefore, users who wish to convert the elevations in this FIS to NGVD29 should apply the stated conversion factor(s) to elevations shown on the Flood Profiles and supporting data tables in the FIS report, which are shown at a minimum to the nearest 0.1 foot.

NGVD29 = NAVD88 + 0.89

For more information on NAVD88, see Converting the National Flood Insurance Program to the North American Vertical Datum of 1988, FEMA Publication FIA-20/June 1992, or contact the Spatial Reference System Division, National Geodetic Survey, NOAA, Silver Spring Metro Center, 1315 East-West Highway, Silver Spring, Maryland 20910 (Internet address http://www.ngs.noaa.gov).

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. To assist in this endeavor, each FIS provides 1-percent annual chance floodplain data, which may include a combination of the following: 10-, 2-, 1-, and 0.2-percent annual chance flood elevations; delineations of the 1- and 0.2-percent annual chance floodplains; and 1-percent annual chance floodway. This information is presented on the FIRM and in many components of the FIS, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevation tables. Users should reference the data presented in the FIS as well as additional information that may be available at the local community map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent annual chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent annual chance flood is employed to indicate additional areas of flood risk in the community. For the flooding sources studied in detail, the 1- and 0.2-percent annual chance floodplains have been delineated using Geographic Information Systems (GIS) technology and digital elevation data.

For this FIS revision, the boundaries were interpolated between cross sections, using topographic datasets from the City of Norfolk that were available in the form of Light Detection and Ranging (LiDAR) Bare Earth files (December, 2008), ESRI Terrain and Raster GRID, and 1-ft contours (Tiled ESRI Feature Class Dataset).

The 1- and 0.2-percent annual chance floodplain boundaries are shown on the FIRM (Exhibit 2). On this map, the 1-percent annual chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AE, AH, AO, and VE), and the 0.2-percent annual chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent annual chance floodplain boundaries are close together, only the 1-percent annual chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

In areas where a wave height analysis was performed, the A, AE, V and VE zones were divided into whole-foot elevation zones based on the average wave crest elevation in that zone. Where the map scale did not permit delineating zones at 1-foot intervals, larger increments were used.

Within this jurisdiction there are one or more levees that have not been demonstrated by the community or levee owner(s) to meet the requirements of Section 65.10 of the NFIP Regulations in 44 CFR as it relates to the levee's capacity to provide 1% annual chance flood protection. As such, the floodplain boundaries in this area were taken directly from the previously effective FIRM and are subject to change. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information on how this may affect the floodplain boundaries shown on the FIRM.

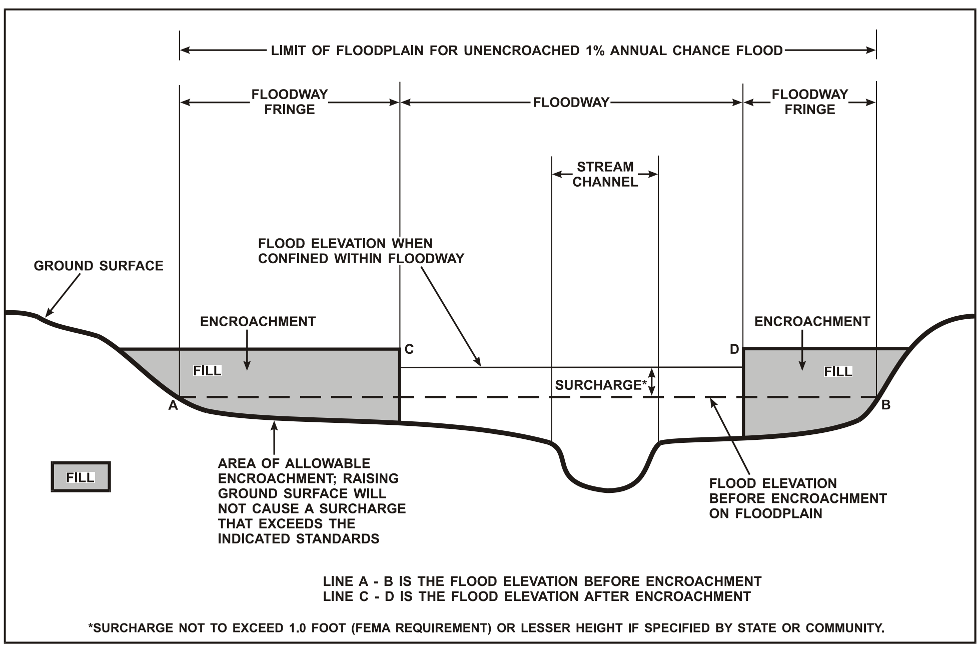
4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent annual chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent annual chance flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced

Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. To reduce the risk of property damage in areas where the stream velocities are high, the community may wish to restrict development in areas outside the floodway.

The area between the floodway and 1-percent annual chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 1-percent annual chance flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 3, "Floodway Schematic."

FIGURE 3: FLOODWAY SCHEMATIC



No floodways were computed as part of this FIS revision.

5.0 INSURANCE APPLICATIONS

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. The zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone AR

Area of special flood hazard formerly protected from the 1-percent annual chance flood event by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1-percent annual chance or greater flood event.

Zone A99

Zone A99 is the flood insurance rate zone that corresponds to areas of the 1-percent annual chance floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No BFEs or depths are shown within this zone.

Zone V

Zone V is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no BFEs are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent annual chance floodplain, areas within the 0.2-percent annual chance floodplain, and areas of 1-percent annual chance flooding where average depths are less than 1 foot, areas of 1-percent annual chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent annual chance flood by levees. No BFEs or depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent annual chance floodplains that were studied by detailed methods, shows selected whole-foot BFEs or average depths. Insurance agents use the zones and BFEs in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 1- and 0.2-percent annual chance floodplains. On selected FIRM panels, floodways and the locations of selected cross sections used in the hydraulic analyses and floodway computations are shown where applicable.

The current FIRM presents flooding information for the entire geographic area for the City of Norfolk.

Within this jurisdiction there are one or more levees that have not been demonstrated by the community or levee owner(s) to meet the requirements of Section 65.10 of the NFIP Regulations in 44 CFR as it relates to the levee's capacity to provide 1% annual chance flood protection. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information on how this may affect the FIRM.

7.0 OTHER STUDIES

Revised FISs and FIRMs are currently being prepared for the adjacent cities of Chesapeake, Portsmouth, and Virginia Beach (FEMA, unpublished).

Because it is based on more up-to-date analyses, this FIS supersedes the previously printed FIS for the City of Norfolk and should be considered authoritative for purposes of the NFIP.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in preparation of this FIS can be obtained by contacting FEMA, Federal Insurance and Mitigation Division, 615 Chestnut Street, One Independence Mall, Sixth Floor, Philadelphia, Pennsylvania 19106-4404.

9.0 BIBLIOGRAPHY AND REFERENCES

Bennett, M. E. (1933). *A Pictorial Record of Tidewater's Worst Storm, August 22 and 23, 1933*. Norfolk, VA,

Center for Operational Oceanographic Products and Services. (2013, October 10). *Tides and Currents*. Retrieved October 16, 2013, from National Oceanic and Atmospheric Administration, National Ocean Service: www.tidesandcurrents.noaa.gov.

City of Norfolk. (2013). *A to Z: History of Norfolk.* Retrieved October 29, 2013, from City of Norfolk Web Site: http://www.norfolk.gov/Index.aspx?NID=429.

Commonwealth of Virginia, Virginia Base Map Program Orthophotography – 2009 (VA State Plane South), Richmond, VA.

Commonwealth of Virginia. (2003, December). *An Assessment: Virginia's Response to Hurricane Isabel*. Richmond, VA.

Commonwealth of Virginia. (1973, September). Article 8, Part C, Section 872.6. *Virginia Uniform Statewide Building Code*.

EarthData International. (2003). *Digital Terrain Model; Compiled at a Scale of 1:3,600, Topographic Mapping Contour Interval of 1 Foot.* Maryland

Federal Emergency Management Agency. (2007a). *Atlantic Ocean and Gulf of Mexico Update Coastal Guidelines Update*. Washington, DC.

Federal Emergency Management Agency. (2011, November 16). *Flood Insurance Study, City of Suffolk, Virginia (Independent City).* Washington, DC.

Federal Emergency Management Agency. (2009, September 2). *Flood Insurance Study, City of Norfolk, Virginia (Independent City).* Washington, DC.

Federal Emergency Management Agency. (unpublished). *Flood Insurance Study, City of Chesapeake, Virginia (Independent City).* Washington, DC.

Federal Emergency Management Agency. (unpublished). *Flood Insurance Study, City of Portsmouth, Virginia (Independent City).* Washington, DC.

Federal Emergency Management Agency. (unpublished). *Flood Insurance Study, City of Virginia Beach, Virginia (Independent City).* Washington, DC.

Federal Emergency Management Agency. (2007b, August). *Wave Height Analysis for Flood Insurance Studies (WHAFIS),* Version 4.0. Washington, DC.

Hurricane Research Division. (n.d.). *Weather Info: Hurricane Frequently Asked Questions*. Retrieved from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Oceanic and Atmospheric Research, Atlantic Oceanographic and Meteorological Research Laboratory: www.aoml.noaa.gov/hrd.

Luettich, R. A. and J.J Westerink. A (Parallel) *Advanced Circulation Model for Oceanic, Coastal and Estuarine Waters (ADCIRC)*. Version 45.12. February 6, 2008. University of North Carolina at Chapel Hill, Institute of Marine Sciences: Morehead City, NC.

National Academy of Sciences (NAS): National Research Council. (1977). *Methodology for Calculating Wave Action Effects Associated with Storm Surges.* Washington, DC: National Academy of Sciences. National Academies Press.

National Oceanic and Atmospheric Administration (NOAA). (2004, April). *NOAA Technical Report NOS CO-OPS 040, Effects of Hurricane Isabel on Water Levels Data Report.* Silver Spring, MD.

Southside Hampton Roads Hazard Mitigation Plan. (September 2011). http://readyhamptonroads.org/Portals/0/Public/Mitigation/SSHR%20Plan%20and%20Figures.pdf.

The Norfolk Ledger Dispatch. (1933, August 23). Norfolk, VA.

The Norfolk Ledger Dispatch and Portsmouth Star. (1962, March 7) Norfolk, VA.

The Portsmouth Star. (1936, September 18). Portsmouth, VA.

The Virginian Pilot. (1962, March 8). Norfolk, VA.

U.S. Army Corps of Engineers (USACE). (2012). *ERDC/CHL TR11-X. FEMA Region 3 Storm Surge Study Coastal Storm Surge Analysis: Modeling System Validation Submission No. 2.*

U.S. Army Corps of Engineers: Galveston District. (1975). *General Guidelines for Identifying Coastal High Hazard Zones.* Galveston, TX.

U.S. Army Corps of Engineers: Norfolk District. (1970, March). *Flood Plain Information Report, Coastal Flooding, Norfolk, Virginia.* Norfolk, VA.

U.S. Census Bureau. (2013). *2010 Population Finder*. Retrieved October 25, 2013 http://www.census.gov/popfinder.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. (2004, May). *Service Assessment: Hurricane Isabel September 18-19, 2003.* Silver Spring, MD.

National Oceanic and Atmospheric Administration. (2006) *Products, Predictions, Published Tide Table.* Retrieved from www.tidesandcurrents.noaa.gov.

Virginia Department of Emergency Management. (2012). *Virginia Hurricane History.* Retrieved from: http://www.vaemergency.gov/readyvirginia/stay-informed/hurricanes/hurricane-history